Demonstration Of A Relocatable Regional Ocean Atmosphere Modeling System with Coastal Autonomous Sampling Networks: Turbulence Characterization from an AUV

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LONG-TERM GOAL

My long term goal is to utilize turbulence measurements obtained from small Autonomous Underwater Vehicle (AUV) based sensors as the subgrid characterization tool in combined coastal ocean observation/prediction networks.

OBJECTIVES

I wish to use AUV-based turbulence measurements to quantify mixing in shallow water physical process studies (upwelling regions, fronts. boundary layers) within the context of the LEO-15 based National Ocean Partnership Program (NOPP) coupled ocean observation/modeling system. This includes estimating mixing levels, identifying regions of enhanced mixing, determining the horizontal spatial scale of mixing events, defining the role of boundary layers, and parameterizing results for coastal predictive model testing studies of subgrid scale processes.

APPROACH

My approach is to integrate an optimum turbulence sensor suite into a small, logistically simple, AUV, and establish this small AUV as a viable platform for coastal turbulence research. Towards this end, I obtain horizontals profiles of dissipation rate, temperature microstructure, 3-dimensional small scale velocity, finescale vertical shear of horizontal current, and stratification in the coastal environment. The sensors provided data for estimates of eddy diffusivity profile (Gargett and Moum (1995), eddy viscosity profile (using the truncated TKE equation), Richardson numbers, and fluxes [using the correlation technique].

Subsequently, I studied mixing in the context of the multi-scale measurements surrounding the NOPP LEO-15 node site in the Mid-Atlantic Bight. I sampled adaptively using the Rutgers University continental shelf model SCRUM (Song and Haidvogel, 1994). These data enable us to evaluate turbulence closure schemes associated with subgrid mixing processes as parameterized by different boundary layer submodels in SCRUM, the coastal circulation model

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Demonstration Of A Relocatable Regional Ocean Atmosphere Modeling System with Coastal Autonomous Sampling Networks: Turbulence Characterization from an AUV</td><td colspan="2">5a. CONTRACT NUMBER</td></tr>
<tr><td colspan="2">5b. GRANT NUMBER</td></tr>
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<tr><td colspan="2">5e. TASK NUMBER</td></tr>
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Naval Undersea Warfare Center, Division Newport,Code 8211,Newport,RI,02841</td><td colspan="2">8. PERFORMING ORGANIZATION REPORT NUMBER</td></tr>
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<tr><td colspan="6">12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited</td></tr>
<tr><td colspan="6">13. SUPPLEMENTARY NOTES</td></tr>
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Same as Report (SAR)</td><td rowspan="2">18. NUMBER OF PAGES
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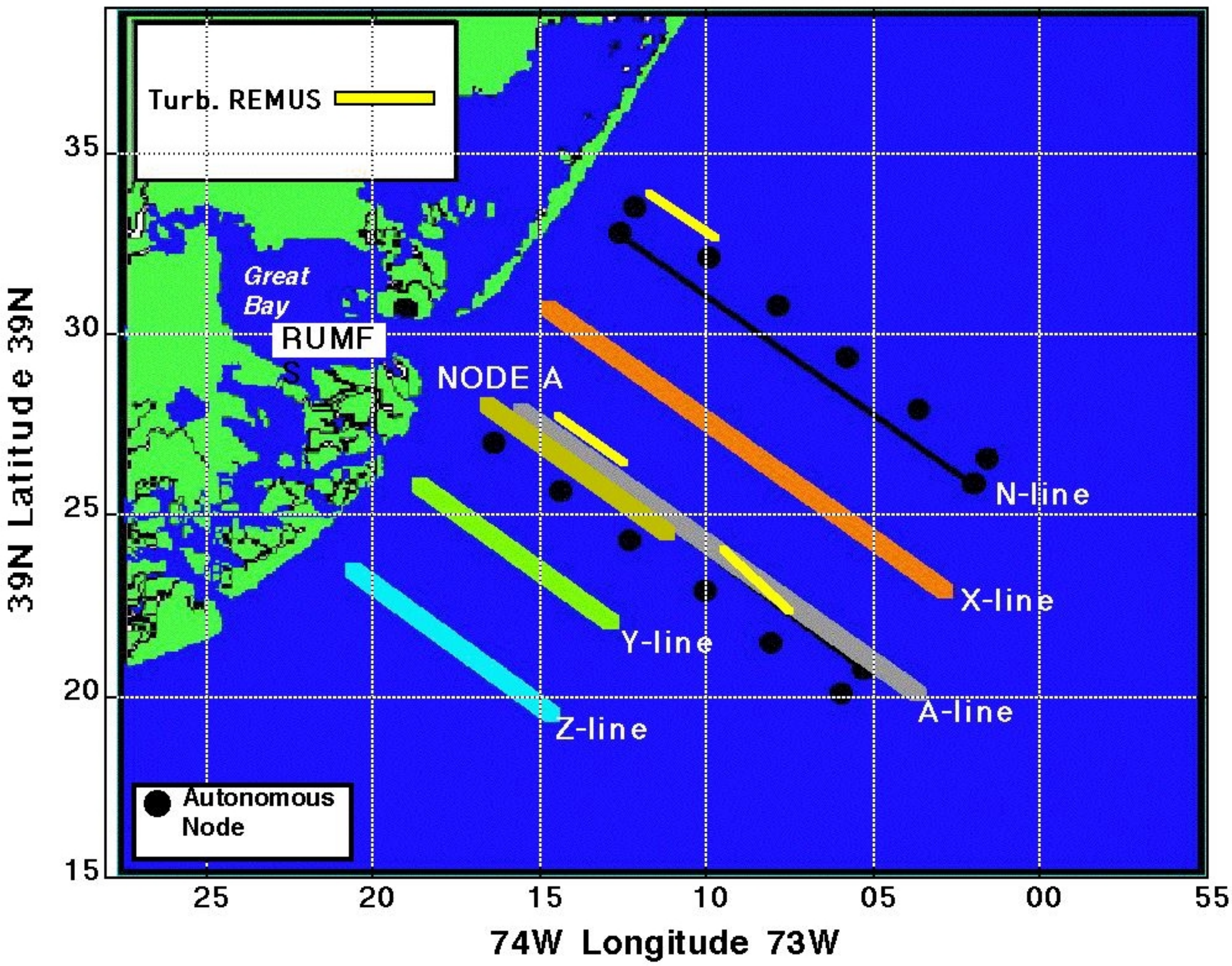
WORK COMPLETED

A turbulence sensor package was electrically and mechanically integrated into the REMUS AUV (Levine and Lueck, 1999). Sensors include two shear probes, an ultra-fast thermistor, an upward and downward looking ADCP, two CTDs, and an ADV-O.

Utilizing these techniques, scientific studies of the Ocean Boundary Layer (OBL) during an upwelling event were conducted near the Rutgers University LEO-15 site on the inner continental shelf off New Jersey during July 1999 (Fig. 1). In the field experiment, high quality data were obtained from all sensors, and data analysis is proceeding well.

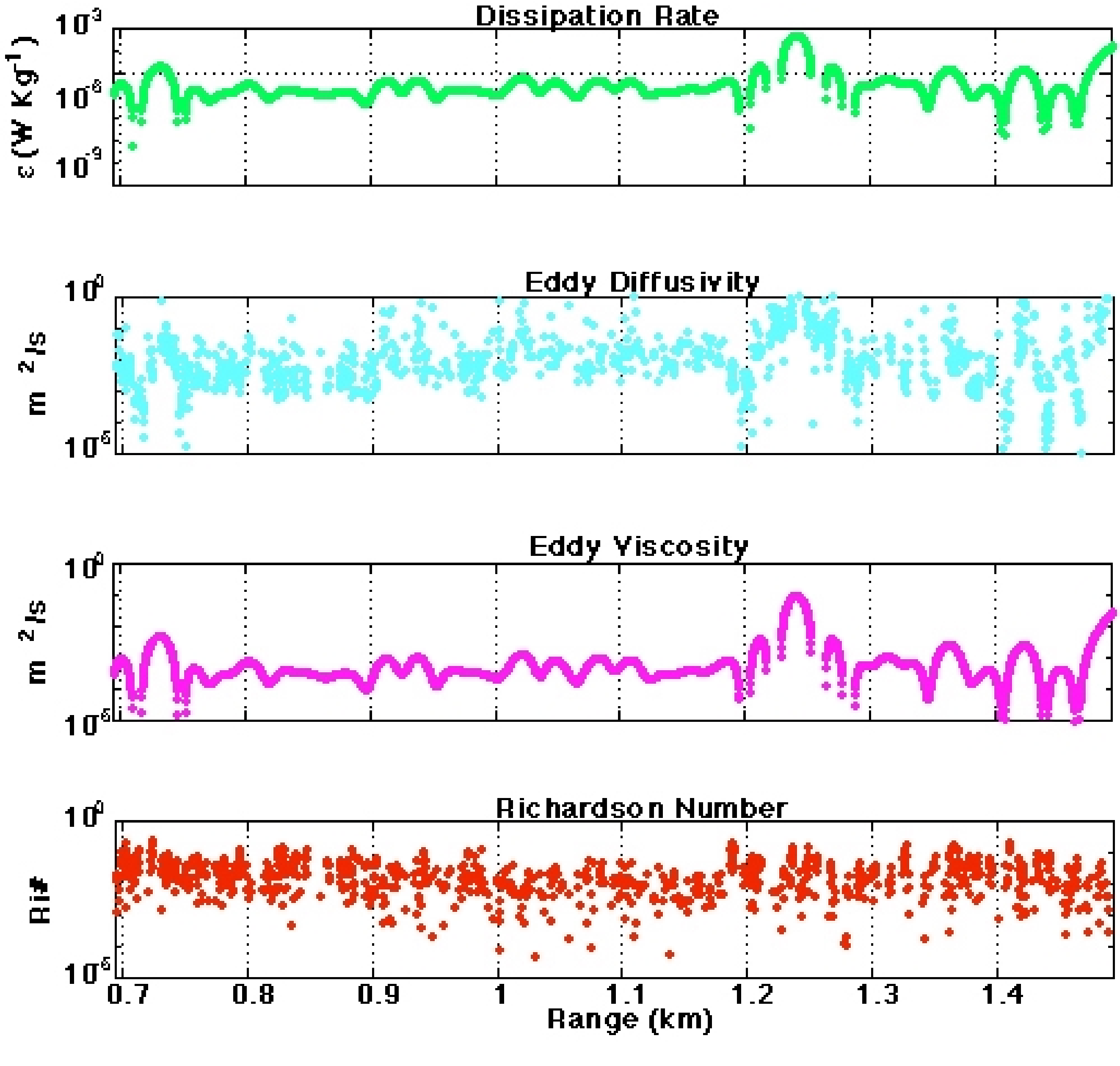


1. AUV trajectories in upwelling region

RESULTS

Using SCRUM model-based adaptive sampling, the AUV was deployed, during July 1999, along a trajectory through components of the Leo-15 upwelling region, including the upstream "pipe" and detached jet. These measurements were made synoptically with those from other platforms which characterize larger scale structures on the nearby continental shelf. Model predictions which include assimilated data from the wide variety of sampling platforms is also available for comparison.

We ran a total of eleven missions in the upstream pipe (N line, inshore), the downstream pipe (A line, inshore) and the detached jet (A line offshore), at a variety of depths in the core of the features, and in the top and bottom layers . During the course of the experiment, approximately 400 megapoints of high quality turbulence data were obtained. An example of the upstream "pipe" turbulence estimation is shown in Fig 2. For a 7 m depth transit, time series of mixing parameter estimates primarily show dissipation rates of 10^{-7} to 10^{-5} W kg $^{-1}$, eddy diffusivities of 10^{-4} to 10^{-1} m^2 s^{-1}, eddy viscosities of 10^{-5} to 10^{-2} m^2 s^{-1}, and Richardson numbers of 10^{-3} to 10^{-1}.



2. Mixing parameters in upstream "pipe"

For the final model prediction cycle, our estimated eddy viscosity in the upstream pipe was utilized as the inshore maximum value for the SCRUM sub-grid scale paramaterization. Subsequent to the experiment, 2-D diagnostic runs of the model (S. Durski, personal communication) show that the data-derived eddy viscosity, and variation around its value can significantly affect the onset and character of the upwelling.

IMPACT/APPLICATION

The AUV-based turbulence measurements provide a unique horizontal profiling view of the variability of the mixing environment that cannot be obtained by more conventionally sampling measurements, and this approach can be further exploited in yo-yoed horizontal sections. These techniques will be invaluable in upwelling process studies in which competing turbulence closure model alternatives are testing in SCRUM to parameterize subgrid processes. Competing OBL alternatives include those of Mellor-Yamada (1974) Large et al. (1994), and Price et al. (1986). Features such as the evolution of the upwelling front can be tested.

TRANSITIONS

Our AUV sensor technologies, hardware and software, are being considered for inclusion as tactical oceanography payloads for the Manta UUV Initiative.

RELATED PROJECTS

Previous studies with the Rutgers group were conducted in 1998-99 under separate NOPP support. My AUV-based turbulence measurement system has been utilized in NOPP studies with the Harvard led LOOPS project, in Cape Cod Bay in September 1998. The system is also being utilized in NOPP FRONT studies on the New England continental shelf during 1999-2001.

REFERENCES

A. E. Gargett and J. N. Moum. 1995. Mixing effects in tidal fronts: results from direct and indirect measurements of density flux. J. Phys. Ocean. , 25, 2583-2608.

W. G., Large, J. C. McWilliams, and S. C. Doney. 1994: Oceanic vertical mixing: a review and model with a non-local boundary parameterization. Rev. Geophys., 32, 363-403.

Levine, E. R., R. G. Lueck, 199. Turbulence measurements with an autonomous underwater vehicle. Journal of Atmospheric and Oceanic Technology, Special Issue on Ocean Turbulence Measurement, 16, 11, part 1, 1533-1544.

G. L. Mellor and T. Yamada. 1974. A hierarchy of turbulence closure models for planetary boundary layers. J. Atmos. Sci., 31, 1791-1806.

J. F Price., R. A. Weller, and R. Pinkel. 1986. Diurnal cycling: Observations and models of the upper ocean response to diurnal heating, cooling, and wind mixing. J. Geophys. Res., 91, C7, 8411-8427.

Y. Song and D. Haidvogel. 1994. A semi-implicit ocean circulation model using a generalized topography following coordinate system. J. Comput. Phys., 115, 228-244.

PUBLICATIONS

Glenn, S. M., D. B. Haidvogel, O. M. E. Scofield, C J. von Alt, and E. R. Levine, 1998: Coastal Predictive Skill Experiments. Sea Tech., April 1998, 66-72.

Levine, E. R., R. G. Lueck, 1999: Turbulence measurements with an autonomous underwater vehicle. Journal of Atmospheric and Oceanic Technology, Special Issue on Ocean Turbulence Measurement, 16, 11, part 1, 1533-1544.

Levine, E. R., R. G. Lueck, R. R. Shell, and P. Licis, 1999: Ocean turbulence estimates in the Coastal Ocean Modeling and Observation Program (COMOP) studies at LEO-15. ASLO 1999 Aquatic Sciences Meeting, Santa Fe. NM, Feb 1999.

Levine, E. R., R. G. Lueck, R. R. Shell, and P. Licis, 1999: Coastal turbulence estimates and physical process studies utilizing a small AUV. Invited paper at 1999 Spring AGU meeting, Boston, MA, June 1999. abstract in. supple. to April 17 EOS, Trans. Am. Geophys. Un., S192.

Levine, E. R., R. G. Lueck, R. R. Shell, and P. Licis, 1999: Coastal turbulence estimates and physical process studies utilizing a small AUV, Proceedings, Eleventh International Symposium on Unmanned Untethered Vehicle Technology (UUST99), Durham, NH. 94-102, Sept. 1999

Levine, E. R., R. G. Lueck, R. R. Shell, and P. Licis, 2000: Coastal Turbulence Estimates in Ocean Modeling and Observation Studies Near LEO-15, accepted for 2000 Ocean Sciences Meeting, Special Session on Coastal Ocean Dynamics and Prediction, Jan 2000, San Antonio. TX.